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Impact of pre and post emergence of herbicides on growth, weed indices and yield attributes of *Bt.* cotton hybrids under high density planting in Maharashtra region

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Abstract
In recent years, the productivity of cotton has been increased substantially by adopting high density planting system in most of the cotton growing countries. An experiment was conducted during *kharif* 2021 at central farm, VNMKV, Parbhani, (MS). Comprised of three population densities 24,691 plants ha^{-1} (D_1), 37,037 plants ha^{-1} (D_2), 55,555 plants ha^{-1} (D_3) and weed management practices, pre-emergence application of pendimethalin @ 1.0 kg ha^{-1} followed by two hand weeding and one hoeing (W_1), pre-emergence pendimethalin followed by post emergence of pyrithiobac-sodium 60% + quizalofop-ethyl (75+50 g ha^{-1}) (W_2), post-emergence pyrithiobac-sodium + quizalofop-ethyl followed by one hand weeding (W_3) and Weedy check (W_4) in split plot during replication three. The maximum growth parameters, yield attributes and seed cotton yield were recorded with the application of pyrithiobac-sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding recorded more seed cotton yield (2019 kg ha^{-1}), net monetary returns (Rs. 1,22,678 ha^{-1}) and benefit cost ratio (2.47) was observed with higher weed control efficiency (56.59%) and significantly higher than other treatment of weed control plant density of 55,555 plant ha^{-1} (90 cm x 20 cm) produce significantly more seed cotton yield (1954 kg ha^{-1}) which was at par with plant density of 37,037 plants ha^{-1} (90 cm x 30 cm) with seed cotton yield of 1767 kg ha^{-1}.

Keywords: HDPS, *Bt.* cotton, weed control efficiency and seed cotton yield

Introduction
Cotton (*Gossypium hirsutum* L.) is one of the most ancient and important commercial crops next to food grains. Due to its importance in agriculture as well as in production economy. It's also known as "White gold". In India cotton is grown over an area 120.69 lakh hectares with production 362 lakh bales and productivity 510 kg lint ha^{-1} (AICRP on cotton 2021-22). In India, the seed cotton yield per unit area is still far below than many other cotton growing countries in the world. Among the various factors responsible for low plant population and use of low potential varieties are the primary importance. Various techniques like maintaining suitable plant density, use of suitable post emergence herbicides etc. are being used to overcome those constraints in cotton production.

It is an important cash crop of Maharashtra region mostly under rainfed situations. In Maharashtra, it is grown an area of 12.85 lakh hectares with productivity of 245 kg lint ha^{-1}, which is too low than other cotton growing states. (AICRP on cotton 2021-22). There is need to increase the production of cotton for improving financial status of farmers and strengthen national economy by increasing the productivity of cotton not only by increasing the area under production but also plant population per hectares. Plant may show better growth and development and give higher yield per plant but may not give maximum yield per unit area because of inadequate plant population. The adoption of high-density planting along with good use of herbicides and better *Bt.* cotton hybrids, ideal viable approach to break the current trend of stagnating yield under primary rainfed *Bt.* cotton growing areas. Cotton is very sensitive to crop weed competition due to low growth during early stages and wider spacing. The critical period of weed complication is up to 45 days after sowing (DAS). Though many pre-emergences herbicide are available for controlling weed, the need for post-emergence herbicide is after realised to control the weeds emerged during later stages of crop growth. Moreover, due to increasing problem of labour availability for cotton cultivation, use of post-emergence herbicides has greater potential for effective weed management.

Pendimethalin control weed by inhibition of microtubules formation in cells. This causes disruption of cell dividing. As the microtubules spindle fibres that guide chromosomes are absent. The cell plate does not appear and cell do not divide. The disoriented and cell expand to a recorded rather than elongated shape. It is a pre-emergence herbicide controlling a wide range of grass and small seed broadcast weed (Byrd *et al.*, 1987) [2]. Pyrithiobac sodium is a broad-spectrum systemic herbicide which inhibits enzyme acetolactate synthase, a key enzyme in biosynthesis of branched chain amino acids. It is reported to control troublesome broad leaf weeds, when applied as post-emergence herbicide at 2-3 leaf stage without affecting the cotton crop (David *et al.*, 2002) [3]. Quizalofop ethyl is a selective systemic herbicide applied at post emergence herbicide for control of annual and perennial grass weeds. It is a bio-chemically acetyl CoA carboxylase inhibitor and inhibitor of fatty acid biosynthesis, herbicide absorbed from leaf surface with translocation throughout the plant moving in both the xylem and phloem and accumulating in the meristematic tissue. The weed can severely decrease cotton productivity. In view of the above, present research work is carried out with the objective to find out the impart of herbicides on weed indices, yield attributing characters under high density planting.

Materials and Methods

The field experiment was conducted to study "Effect of high-density planting and weed management practices on weed dry matter, weed indices and seed cotton yield of *Bt*. cotton under rainfed condition" during *kharif* 2021-2022 at central farm, department of agronomy and college of agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (M.S) India.

Treatment details

1. Main treatment

Density

D_1- 90 x 45 cm^2 (24,691 plants ha^{-1})
D_2- 90 x 30 cm^2 (37,037 plants ha^{-1})
D_3- 90 x 20 cm^2 (55,555 plants ha^{-1})

2. Sub treatment

Weed management

W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1}(a.i) followed by two hand weeding and one hoeing.
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 60% + quizalofop-ethyl 50% (75+50) gm. a.i. ha^{-1} @ 25- 30 DAS.
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.
W_4: Weedy check.

Other experimental details

1. Season: Central Farm of VNMKV, Parbhani
2. Soil type: Vertisol
3. Crop: *Bt*. cotton
4. Hybrid: Ajeet-5
5. Name of Design: Split plot design
6. Treatment: 12
7. Replication: 03
8. Number of plots: 36
9. Plot size: Gross = 6.3 m× 5.4 m
   Net = 4.5 m × 3.6 m
10. Distance between plot: 0.70 m
11. Distance between replication: 1 m
12. Spacing: As per treatment
13. Method of sowing: Dibbling
14. Date of sowing: 8 July 2021
15. Site: At field of Central Farm, Balsa, VNMKV, Parbhani.

Weed control efficiency (WCE)

Formula given by Mani *et al*., (1973) [9].

$$WCE\ (\%) = \frac{DMc - DM_T}{DMc} \times 100$$

Where,
WCE - Weed control efficiency in per cent
DMc - Dry weight of weeds in unweeded check
DM_T - Dry weight of weeds in treated plot

Weed index (WI): The weed index was calculated by the formula proposed by Gill and Vijay Kumar (1969) [5].

$$Weed\ Index\ (\%) = \frac{X-Y}{X} \times 100$$

Where,
WI - Weed index in per cent
X - Yield from minimum weed competition plot
Y - Yield from treatment plot

Result and Discussion

Weed control efficiency

Data pertaining to weed control efficiency is presented in Table 1. at 30 and 60 DAS, the treatment which was scheduled with 55,555 plants ha^{-1} (D_3) recorded maximum weed control efficiency (WCE) of 51.48% and 56.82% respectively, but 90 and 120 DAS the maximum WCE of 48.94 and 45.10% was registered due to 55,555 plants ha^{-1} (D_3) than normal planting density i.e., 24691 plant ha^{-1}(D_1). At harvest stage also maximum WCE of 41.87% was registered more 55,555 plants ha^{-1} (D_3). The lowest WCE of 46.83, 51.67 and 42.79 per cent were recorded due to scheduling of 37,037 plants ha^{-1} (D_2) as compared to plant density at 30, 60, 90 DAS respectively. however, at 120 DAS the treatment schedule with 24,691 plants ha^{-1} (D_1) registered the lowest WCE 34.46%. Among the weed management practices at 30 DAS the highest WCE of 66.50 percent was noticed due to post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) i.e., (W_3) but later stage the highest WCE of 71.54, 63.18, 60.35 and 58.01 percent were registered with the applicable post-emergence pyrithiobac sodium (60.0 g ha^{-1}) + quizalofop-ethyl (50 g ha^{-1}) at 60, 90, 120 and at harvest stage respectively.
The lowest WCE was registered under weedy check (W4) treatment during all the stages of crop growth. The higher WCE was attributed due to lower dry weight of weeds. This might be due to efficiency weed control achieved under effective method of weed management in terms of reduced biomass of weed and higher weed control efficiency. This similar result observed by Singh and Rathod (2015) [13], Veeraputhiran and Shrinivasan (2015) [14].

Weed Index

The data pertaining to weed index (WI) is presented in Table 1. Among the plant densities, the lowest (WI) 7.25 percent

was recorded, due to the scheduling of 55,555 plants ha^{-1} (D_3) than the normal planting and highest (WI) of 28.98 per cent was registered due to the scheduling of 24,691 plants ha^{-1}(D_1). The weed index was reduced in herbicide applied treatment, when compared to control treatment (W_4). Among weed management practices the lowest WI 3.98 per cent was drastically by the application of post-emergence pyrithiobac sodium (60.0 g ha^{-1}) + quizalofop-ethyl (50 g ha^{-1}) at 20 and 40 DAS (WI) and the highest WI 42.21 per cent was registered in weedy check (W_4). In unweeded control (W_4), higher weed index values indicate reduced yield due to weeds. The reduce weed index value might be due to higher dry matter accumulation of weeds. Consequently, reduced the seed cotton yield. The finding are in agreement with those of Hiremath *et al.,* (2014) [6] and Shelke *et al.,* (2013) [15].

Effect of weed management practices

All chemical weed control method alone and in combination with other herbicide significantly increased the boll weight, boll per plant, seed cotton yield per plant (g) and seed cotton yield kg ha^{-1} as compared to weedy check in Table 1. Application of post emergence Pyrithiobac sodium @ 60.0 g ha^{-1} + Quizalofop-ethyl 50g ha^{-1} at 20-25 DAS + one hand weeding 40 DAS produced maximum 16.65 bolls plant^{-1} and found significantly superior over rest of weed management treatments. Application of pre emergence pendimethalin followed by post emergence of Pyrithiobac sodium 60.0 g ha^{-1} + Quizalofop-ethyl 50.0 g ha^{-1} at 20-30 DAS which was at par with pendimethalin @ 1000 g ha^{-1} + two hand weeding and hoeing and significantly superior over weedy check. The higher yield attributes in the above treatments were due to lesser weed competition, which in turn might have allowed crop plants to grow better with proper utilization of available resources without competition of weeds, similar results were also observed by Madhu *et al.,* (2014) [8].

The favourable result of effective weed control with higher seed cotton yield by the post emergence herbicide pyrithiobac sodium in cotton reported by Hiremath *et al.,* (2014) [6]. Further, timely and efficient control of weeds through herbicide compared with cultural methods. Which resulted in better availability of soil moisture and nutrients uptake (Prabhu *et al.,* 2012) [10].

Harvest Index (%)

Effect of plant densities

Higher harvest index value (37.48%) was noticed with 55,555 plants ha^{-1} followed by 37,037 plants ha^{-1} than normal planting. The lowest harvest index was recorded with 24,691 plants ha^{-1}. High plant density produced the greatest biological yield with highest harvest index.

Effect of weed management practices

Higher harvest index (38.58%) was noticed with mix application of pyrithiobac sodium 60.0 g ha^{-1} + quizalofop-ethyl 50.0 g ha^{-1} at 20-25 DAS + one hand weeding 40 DAS. The lowest harvest index value was recoded with unweeded control (30.14%) treatment. The maximum boll weight was observed with pyrithiobac sodium 60.0 g ha^{-1} + quizalofop-ethyl 50.0 g ha^{-1} at 20-25 DAS + one hand weeding 40 DAS. Which was significantly superior over rest of weed management treatment practices.

The lowest yield of only 1167 kg ha^{-1} was recorded by unweeded check indicating yield reduction due to weeds accounted 73.00% during 2021-2022. The higher seed cotton yield in pyrithiobac sodium 60.0 g ha^{-1} + quizalofop-ethyl 50.0 g ha^{-1} at 20-25 DAS + one hand weeding 40 DAS weed treatment was attributed to lesser weed population and weed dry weight compared with higher yield attributes. This might be due to the fact that weeds were controlled by spray of grassy herbicide (quizalofop-ethyl) and broad leaf herbicide (pyrithiobac sodium) at 2-3 weed leaf stage and the weed emerged latter and were recorded by hand weeding at 40 DAS due to reduced number of bolls, boll weight and seed cotton yield plant^{-1}.

Table 1: Weed control efficiency (%) and Weed Index of *Bt.* cotton hybrid under varied plant spacing and weed management practices as influenced by different treatments during 2021-2022

Treatments	30 DAS	60 DAS	90 DAS	120 DAS	At Harvest	Weed index (%)
A. Density						
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	35.28	38.81	37.34	41.29	34.46	28.98
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	46.84	51.67	42.79	40.06	39.65	12.48
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	50.34	55.64	45.44	43.79	41.86	7.25
B. Weed management						
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	57.82	64.79	54.90	51.86	50.94	11.84
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 60% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 20-25 DAS.	52.01	58.50	50.02	49.46	45.67	15.48
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	66.60	71.54	63.18	60.35	58.00	3.98
W_4: Weedy check.	-	-	-	-	-	42.21
GM	51.48	56.82	48.94	47.80	45.09	17.46

Yield attributing characters and seed cotton yield

Effect of plant densities

The data represented in Table 2 indicate that the difference due to various plant densities in respect of boll weight (g) was significantly influenced. A wider plant spacing of 90 cm x 45 cm produced more boll weight (g). The variation in boll weight in plant densities was due to fact that the better aeration and adequate interception of solar radiation and lesser competition of nutrients and moisture in wider spacing. Which resulted in synthesis of higher photosynthesis and there by helped to produced higher boll weight. Significantly less number of boll plant^{-1} was observed with 55,555 plant ha^{-1} (90 cm x 20 cm) treatment. The result is in conformity with Dong *et al.,* (2010) [4], where high plant density increased the

number of bolls per unit area relative to low plant densities. Difference in respect of seed cotton yield plant^{-1} were significantly among the wider spacing with 64.54 g plant^{-1}. This increase in seed cotton yield might be due to a greater number of boll weight per plant as compare to closer spacing. wider plant spacing of 90 cm x 45 cm i.e., 64.54 g plant^{-1} recorded significantly higher weight of seed cotton yield plant^{-1} as compared to plant spacing of 90 cm x 30 cm (53.02 g) and 90 cm x 20 cm (39.07 g).

This might be due to overall improvement in growth attributes and its position effect on number of boll plant^{-1} under wider plant spacing. The above results are in conformity with the findings of Reddy and Gopinath (2008) [12].

Cotton planted at 24,691 plants ha^{-1} with wider spacing of 90 cm x 45 cm recorded more seed cotton yield plant^{-1} and proved superior over rest of the plant densities Table 3, the differences due to plant spacing in seed cotton yield kg ha^{-1} was significant, closer plant spacing of 90 cm x 20 cm recorded significantly higher seed cotton yield 1954 kg ha^{-1} over the wider spacing of 90 cm x 45 cm and found at par with plant spacing of 90 cm x 30 cm. It was observed that number of boll plant^{-1} were highest under the wider spacing but the seed cotton yield was highest in closer spacing due to the higher plant population than the wider spacing i.e., 90 cm x 45 cm. Similar results were also recorded by Khargakharate *et al.*, (2017) [7] and Pradeep Kumar *et al.*, (2017) [11].

Table 2: Seed cotton yield (kg ha^{-1}), cotton stalk yield (Kg ha^{-1}), biological yield (Kg ha^{-1}) and harvest index (%) of *Bt.* cotton hybrid as influenced by different treatments during 2021-2022

Treatments	Number of picked bolls plant^{-1}	Average boll weight (gm)	Seed cotton yield plant^{-1} (gm)	Seed cotton yield (Kg ha^{-1})	Harvest index (%)
A. Density					
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	17.70	3.64	64.54	1434.15	34.91
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	14.85	3.56	53.02	1767.26	36.07
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	11.89	3.28	39.07	1954.00	37.48
S.E(m)±	0.38	0.12	1.65	51.56	
CD at 5%	1.47	NS	6.48	198.23	
B. Weed management					
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	15.34	3.50	54.05	1780.29	36.88
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS.	14.86	3.46	51.58	1707.00	36.25
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	16.65	3.64	60.99	2019.36	38.58
W_4: Weedy check.	12.42	3.37	42.21	1167.03	30.14
S.E(m)±	0.18	0.06	0.92	51.18	-
CD at 5%	0.54	NS	2.73	152.03	-
Interaction (D X W)					
S.E(m)±	0.31	0.07	1.59	120.13	-
CD at 5%	NS	NS	NS	NS	-
GM	14.82	3.49	52.21	1718	36

Conclusion

The plant density and weed management treatments did not affect quality parameters. Experiment can be concluded that the adoption of plant spacing of D_2-90 cm x 30 cm (37,037 plant ha^{-1}) performed very well by giving yield about 1767 kg ha^{-1} which was aided with treatment of post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3), which were given higher seed cotton yield 2019 kg ha^{-1} found productive, remunerative and profitable under rainfed condition for Marathwada region in Maharashtra

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